EUV holographic aerial image monitoring

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Extreme ultraviolet (EUV) lithography is a promising candidate for sub-100-nm lithography. This method continues on the path of projection optical systems but with a radical reduction in wavelength (10-15 nm) and conversion to lower numerical aperture (NA), all reflective system. EUV systems require unprecedented fabrication tolerances and hence unprecedented metrology accuracy.[1] Here we describe an at-wavelength holographic image recording technique expressly developed to monitor coherent imaging performance of high quality lithographic optical systems.

Holographic aerial image monitoring at EUV wavelengths using a synchrotron-based source has been demonstrated for the first time. The system has been implemented by modifying the EUV phase-shifting point diffraction interferometer (PS/PDI)[2] recently developed at the Advanced Light Source at Lawrence Berkeley National Laboratory.

When a suitably coherent reference wavefront interferes with a wavefront diffracted or scattered by an object, electric-field information, including amplitude and phase, of the object can be recorded. This holographic information can be used to reconstruct the original object distribution. The goal of the experiment described here is to record a hologram of a coherent image generated by a prototype EUV lithographic optic. In this case, the image formed by the EUV optic serves as the object distribution. The image-plane distribution can be reconstructed from this hologram, thereby, qualifying the imaging performance of the optic.

The holographic aerial image recording technique is a simple and compact method that allows image monitoring without printing in photoresist.[5] While this holographic method is restricted to coherent imaging, and lithographic printing typically employs partially coherent light, the partially coherent imaging performance can be predicted from the coherent image. This technique can also be used to characterize the coherence characteristics of illuminators, aiding in the development of synchrotron-based illumination systems.

The holographic aerial image monitoring presented here is based on lensless Fourier-transform holography.[3] The optic used in the experiment is a 10×-Schwarzschild optical system designed to operate at 13.4-nm wavelength. The rms wavefront error of the optic used has been previously reported to be 0.99 nm.[4]

Holographic reconstructions of various image distributions, including ones due to phase-shift-enhanced masks, have been successfully demonstrated and verified by way of computer simulation. Results reveal that the holographic aerial image recording method can be successfully used as a coherent-image-monitoring tool for EUV lithography applications. The holographically reconstructed image of letter based objects, ‘CXRO’ and ‘LBNL’ logo, are described in Figs 1 and 2 respectively. The large letter indicates 200-nm wide lines and small letter indicates 100-nm wide lines.

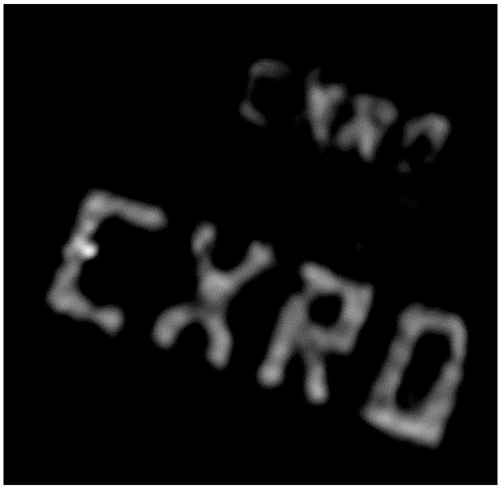

Fig. 1 Holographically reconstructed image of 'CXRO' logo. The large letters corresponds to 200-nm wide, and the smaller letters indicates 100-nm wide lines.

Fig. 2 Holographically reconstructed image of 'LBNL' logo. The large letters corresponds to 200-nm wide, and the smaller letters indicates 100-nm wide lines.

REFERENCES

1. D.M. Williamson, in OSA Proceedings on Extreme Ultraviolet Lithography **23**, edited by F. Zernike and D. T. Attwood, Optical Society of America, Washington, D.C., 68-76 (1994).
2. H. Medecki, E. Tejnil, K.A. Goldberg, and J. Bokor, Opt. Lett. **21** (19), 1526-28 (1996).
3. J. Goodman, "Introduction to Fourier Optics," 2nd Edition, McGraw Hill (1996).
4. P. Naulleau, K.A. Goldberg, S.H. Lee, C. Chang, C. Bresloff, P. Batson, D. Attwood, and J. Bokor, Proc. SPIE **3331**, 114-23 (1998).
5. S. Lee, P. Naulleau, K. A. Goldberg, and J. Bokor, "EUV holographic aerial image recording," SPIE Microlithography Conference in Emerging Lithographic Technologies III, Proc. SPIE 3997, to be published (2000).

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